

# Description

## Data Cartridge Library

### FIELD OF THE INVENTION

[0001] The present invention is directed to a data cartridge library that is useful in storing data on a recording medium located in a cartridge and/or retrieving data from a recording medium located in a cartridge.

### BACKGROUND OF THE INVENTION

[0002] Presently, data cartridge libraries are primarily used to archive data, i.e., store data that is not immediately needed by a host computer, and provide archived data to the host computer when the data is needed. To elaborate, the typical data cartridge library receives data from a host computer and causes the data to be stored or recorded on the recording medium located in one or more cartridges. When the host computer requires some of the data that was previously stored in a data cartridge, a request for the data is sent from the host computer to the library. In response, the library identifies the data cartridge(s) in which

the desired data is located, retrieves the data from the recording medium with the cartridge(s), and transmits the retrieved data to the host computer system.

[0003] Presently, most data cartridge libraries are comprised of:

- (a) a frame/chassis/cabinet that defines an interior space;
- (b) a magazine structure that is located within the interior space and that provides a plurality of data cartridge storage spaces, which are each capable of accommodating at least one data cartridge;
- (c) one or more drives that are each located within the interior space and capable of writing data onto a recording medium located in a data cartridge and/or reading data from the recording medium located in a data cartridge;
- (d) a data cartridge transport device that is located within the interior space and capable of moving an individual data cartridge between any one of the plurality of data cartridge storage spaces and any one of the drives within the library; and
- (e) an interface for receiving data from and transmitting data to a host computer.

[0004] Typically, such a data cartridge library is capable of both storing data provided by a host computer and retrieving data previously stored in the library for the host computer. The storage of data involves using the transport

device to move a data cartridge from one of the data cartridge storage spaces to a drive, using the drive to write the data provided by the host computer on the recording medium located within the cartridge, and after the data has been written on the recording medium, using the transport device to move the data cartridge from the drive to a data cartridge storage space. The retrieval of data involves using the transport device to move a data cartridge from one of the data cartridge storage spaces to a drive, using the drive to read the data on the recording medium located within the cartridge and provide the read data to the host computer, and after the data has been read from the recording medium, using the transport device to move the data cartridge from the drive to a data cartridge storage space.

[0005] As previously noted, a data cartridge library is comprised of a data cartridge transport that is capable of being used to move a data cartridge between any one of the magazine data cartridge storage locations and any one of the drives in the library. Typically, the data cartridge transport device is comprised of a picker and an elevator that moves the picker within the interior space. The picker is capable of inserting/extracting a data cartridge into/from any one

of the magazine storage spaces and any one of the drives. Typically, the picker is comprised of: (a) a grasping device that is used to engage a data cartridge and (b) a pusher plate that carries the grasping device and that is capable of movement towards and away from a location that is capable of accommodating a data cartridge. The elevator serves to position the picker adjacent to a location that is capable of accommodating a data cartridge so that the picker can perform an insertion or extraction operation.

[0006] In an extraction operation, the elevator is used to position the picker adjacent to a space at which a data cartridge is located (typically, either a storage space associated with the magazine or a drive). After the picker has been positioned, the pusher plate is used to move the grasping device towards the data cartridge. After the grasping device has been positioned, the grasping device is then actuated to grasp the cartridge. At this point, the pusher plate is then moved away from the location at which the data cartridge was located to extract the data cartridge from the space.

[0007] In an insertion operation, the elevator is used to position the picker (which is assumed to be grasping a data cartridge) adjacent to the space at which a data cartridge is

to be located. After the picker has been positioned, the pusher plate is then used to move the grasping device and the grasped data cartridge towards the space in which the data cartridge is to be located. After the pusher plate and grasping device have positioned the data cartridge in the space, the grasping device releases the data cartridge, and the pusher plate is moved away from the space to retract the grasping device.

[0008] Many data cartridge libraries are also comprised of an entry/exit port that allows a user to insert and/or extract a data cartridge from the library without powering down the transport device. To elaborate, absent an entry/exit port, if a user wants to insert/extract a data cartridge into/from a library, the user typically powers down the transport device to avoid being injured by the transport device during the insertion or extraction of the data cartridge. The entry/exit port allows a user to insert/extract a data cartridge into/from the library without being exposed to the transport device. As a consequence, the entry/exit port allows a data cartridge to be inserted/extracted into/from the library without having to power down the transport device. Typically, an entry exit port is comprised of a slot structure that defines at least one slot that is capable of

accommodating at least one data cartridge and a device that places the structure in one of two states. In the first state, the device positions the slot structure such that a slot is exposed to the exterior environment. When the structure is in this state, a user can either insert a data cartridge into the slot or remove a data cartridge from the slot, without being exposed to the transport device in either case. In the second state, the device positions the slot structure such that a slot is exposed to the interior of the library and accessible by the transport device, which can either insert a cartridge into the slot or remove a cartridge from the slot. When the structure is in the second state, the user is not exposed to the transport device.

[0009] One type of entry/exit port that has evolved is comprised of: (a) a frame or support to/from which a magazine that can accommodate multiple data cartridges can be attached/detached; and (b) a device for placing the frame in one of the states. In the first state, the device positions the frame such that the frame is exposed to the exterior environment. When the structure is in this state, a user can either attach a magazine to the frame or detach a magazine from the frame. Further, the user can either insert/remove one or more data cartridges into/from the

magazine. In the second state, the device positions the frame such that any magazine that is attached to the frame is exposed to the transport device. In this state, the transport device can load data cartridges into the magazine or remove data cartridges from the magazine, as needed. When the frame is in either state, a user is substantially shielded from the transport device.

[0010] Many data cartridge libraries also have a hinged door that allows a user access to the interior of the library. Typically, such a door is provided so that the transport device can be accessed for maintenance and repair.

#### **SUMMARY OF THE INVENTION**

[0011] The present invention is directed to a data cartridge library that is comprised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine that provides a plurality of data cartridge storage spaces that are each capable of accommodating at least one data cartridge; (c) a drive that is capable of writing data onto a recording medium located within a cartridge and/or reading data from a recording medium located in a cartridge; (d) a picker that is capable of being used to insert and extract a data cartridge from a space that is capable of accommodating a data cartridge; and (e) an elevator for moving the picker within the library

so that a data cartridge can be transported between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library.

[0012] In one embodiment, the data cartridge library comprises a picker that is comprised of: (a) a base plate that is operatively connected to an elevator; (b) a grasper that is operatively connected to the base plate and comprised of a pair of members that are capable of being placed in a closed position that is suitable for grasping a data cartridge and an open position that is suitable for releasing a grasped data cartridge; and (c) a crank that is operatively connected to the base plate and capable of rotating about an axis. The picker further comprises a grasper cam structure comprised of a cam driver that is associated with the crank and a cam follower that is associated with the grasper. The cam driver and the cam follower are situated such that rotation of the crank brings the cam driver into contact with the cam follower and, in so doing, places the grasper in one of the closed position and the open position. Unlike known pickers that employ a crank and a cam structure to actuate a grasper, the grasper is placed in a closed position over a first range of rotation of the crank and an open position over a second range of rotation of



the crank that substantially does not overlap with the first range of rotation. In one embodiment, the first and second ranges are each about 180 degrees.

[0013] In one embodiment, the data cartridge library comprises a picker that is comprised of: (a) a base plate that is operatively connected to an elevator; (b) a grasper that is operatively connected to the base plate and comprised of a pair of members that are capable of being placed in a closed position that is suitable for grasping a data cartridge and an open position that is suitable for releasing a grasped data cartridge; and (c) a crank that is operatively connected to the base plate and capable of rotating about an axis. The picker further comprises a grasper cam structure comprised of a cam driver that is associated with the crank and a cam follower that is associated with the grasper. The cam driver and the cam follower are situated such that rotation of the crank brings the cam driver into contact with the cam follower and, in so doing, places the grasper in one of the closed position and the open position. Unlike known pickers that employ a crank and a cam structure to actuate a grasper, the crank is capable of rotating through more than 180 degrees.

[0014] In one embodiment, the crank is capable of rotating

through 360 degrees. In a particular embodiment in which the crank is capable of such a rotation, the picker is further comprised of a pusher plate that supports the grasper and a pusher plate cam structure that is used to move the pusher plate towards and away from a space that is capable of accommodating a data cartridge. The pusher plate cam structure is comprised of a pusher plate cam driver that is associated with the crank and a pusher plate cam follower that is associated with the pusher plate. The grasper cam structure and pusher cam structure are situated such that: (a) for 180 degrees of a 360 degree rotation of the crank, the grasper is placed in a closed position and the pusher plate can be moved between a fully retracted and a fully extended position; and (b) for the other 180 degrees of a 360 degree rotation of the crank, the grasper is placed in an open position and the pusher plate can be moved between a fully retracted position and a fully extended position.

[0015] In another embodiment, the data cartridge library is comprised of a picker that is, in turn, comprised of a base plate, grasper, crank that is capable of rotation about an axis, and a grasper cam structure. The grasper cam structure is comprised of a cam driver that is associated with

the crank and a cam follower that is associated with the grasper. The grasper cam driver has a surface vector that is not substantially perpendicular to the axis or rotation of the crank. In one embodiment, the grasper cam driver comprises a bubble-like or spherical section that has such a surface vector. In a further embodiment, the picker is comprised of a pusher plate and a pusher plate cam structure with a pusher plate cam driver that is associated with the crank. The pusher plate cam driver has a surface vector, in contrast to the grasper cam driver, that is substantially perpendicular to the axis of rotation of the crank. In one particular embodiment, the pusher plate cam structure operates to move the pusher plate in a direction that is substantially perpendicular to the axis of rotation of the crank and the grasper cam structure operates such that the grasper cam follower is displaced in a direction that at least has a component vector that is parallel to the axis of rotation of the crank.

[0016] In another embodiment, a data cartridge library is provided that allows a user to readily remove/insert a transport module from/into the library, where the transport module is comprised of a picker and a substantial portion of an elevator. In one embodiment, the library is com-

prised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine; (c) a drive; (d) a picker that is capable of being used to insert and extract a data cartridge from a space that is capable of accommodating a data cartridge; and (e) an elevator for moving the picker within the library so that a data cartridge can be transported between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library. The library is further comprised of a transport module that is comprised of a support structure, a portion of the elevator that is connected to the support structure, and the picker. A user-actuable connector is also provided that allows a user to attach the transport module to the frame of the library and to detach the transport module from the frame so that the module can be removed from the library.

[0017] In one embodiment of a data cartridge library with a removable/insertable transport module, the elevator is comprised of an elevator carriage that supports the picker, a first drive system for driving one end of the carriage, a second drive system for driving the other end of the carriage, an electric motor that is operatively connected to the first drive system and provides the first drive system with energy for moving the first end of the

carriage. The elevator is further comprised of a shaft that connects the first drive system to the second drive system, thereby allowing energy from the motor to be transferred through the first drive system to the second drive system. So that the transport module can be removed from the library, the shaft is capable of be separated into two pieces by actuation of a user-actuatable connector. In one embodiment, the connector is comprised of a spline associated with a free end of one piece of the shaft and a spline collar that is associated with the free end of the other piece of the shaft. By sliding the spline collar away from the spline, the two pieces of the shaft are disconnected to facilitate removal of the transport module from the library. To connect the two pieces of the shaft, the free ends of the shaft are aligned and the spline collar is slide over the spline.

[0018] In yet another embodiment, a data cartridge library is provided in which a shaft, rather than a pulley system, is used to connect two drive structures that are used to drive the ends of an elevator carriage that supports a picker. In one embodiment, the library is comprised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine; (c) a drive; (d) a picker that is capable of being used to insert and ex-

tract a data cartridge from a space that is capable of accommodating a data cartridge; and (e) an elevator for moving the picker within the library so that a data cartridge can be transported between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library. The elevator is comprised of an elevator carriage that supports the picker, a first drive system for driving one end of the carriage, a second drive system for driving the other end of the carriage, an electric motor that is operatively connected to the first drive system and provides the first drive system with energy for moving the first end of the carriage. The elevator is further comprised of a shaft that connects the first drive system to the second drive system, thereby allowing energy from the motor to be transferred through the first drive system to the second drive system.

[0019] In yet another embodiment, a data cartridge library is provided with a door that allows a user access to the interior of the library and that is not constrained to rotate about an axis when moving between open and closed positions. In one embodiment, the library is comprised of: (a) a frame/chassis/cabinet with a top surface, bottom surface, and side surface extending between the top and

bottom surfaces; (b) a data cartridge magazine; (c) a drive; (d) a picker that is capable of being used to insert and extract a data cartridge from a space that is capable of accommodating a data cartridge; and (e) an elevator for moving the picker within the library so that a data cartridge can be transported between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library. The library is further comprised of a user interface that is associated with the side surface of the frame and is exposed to the exterior environment. In various embodiments, the user-interface comprises an output terminal for providing a user with information relating to the library, an input terminal for allowing a user to interact with the library, an entry/exit port, and combinations of the these elements. The side surface is comprised of a displaceable portion that accommodates the user interface. The displaceable portion is capable of being placed in an "open" condition that allows a user access to the magazine, drive(s), picker and elevator and a "closed" condition that prevents user access to the noted elements. The library further comprises a user-actuatable connector that permits a user to place the displaceable portion in either the open or closed con-

ditions. However, unlike hinged doors, the displaceable portion and the user-actuatable connector do not constrain the displaceable portion to rotate about an axis in moving between open and closed positions. In one embodiment, the user-actuatable connector comprises one or more captured screws that allow the displaceable portion to be detached from the frame to expose the interior of the library or attached to the frame to cover the interior of the library.

[0020] In another embodiment, a data cartridge library is provided that has a multi-piece magazine. In one embodiment, the library is comprised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine; (c) a drive; (d) a picker that is capable of being used to insert and extract a data cartridge from a space that is capable of accommodating a data cartridge; and (e) an elevator for moving the picker within the library so that a data cartridge can be transported between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library. In one embodiment, the magazine is a multi-piece structure that forms a channel with a first side, a second side, and a back side that extends between the first and second sides. The first, second and back



sides cooperatively define an interior space that is capable of accommodating a plurality of data cartridges. The multi-piece magazine structure is comprised of: (a) a first structure that is in the form of a U-shaped channel that forms portions of the first and second sides of the magazine and the back side of the magazine; (b) a second structure that forms portions of the first and second sides; and (c) a coupler for connecting the first and structures to one another. The first structure also serves as a portion of the frame of the library and, in one embodiment, is made of metal. The second structure is made of the same type of material as the cartridges (typically, plastic) in one embodiment.

[0021] The present invention further provides a multi-piece magazine that is suitable for use in a data cartridge library. In one embodiment, the magazine resulting from the joining together of the various pieces forms a channel with a first side, a second side, and a back side that extends between the first and second sides. The first side, second side and back side cooperatively define an interior space that is capable of accommodating a plurality of data cartridges. The multi-piece magazine structure is comprised of: (a) a first structure that forms at least a portion

of the back side of the magazine; (b) a second that structure that forms at least portions of the first and second sides; and (c) a coupler for connecting the first and second structures to one another. In one embodiment, the first structure is in the form of a U-shaped channel that forms portions of the first and second sides of the magazine and a substantial portion of the back side of the magazine. The second structure, in addition to providing at least portions of the first and second sides of the magazine, further comprises a pair of end sides that are separated from each other and that each connect the portions of the first and second sides provided by the second structure to one another, thereby forming a closed-loop structure. The coupler connects the first and second structures to one another so as to form a box-like, magazine structure with an open side through which cartridges can be inserted/removed into/from the magazine structure.

[0022] The present invention also provides a magazine that is capable of being attached/detached to/from an entry/exit port structure. The magazine is comprised of: (a) a box structure with a bottom wall and a side wall that extends from the bottom wall to a terminal edge that defines an

opening for the insertion/extraction of data cartridges into/from the magazine; (b) a plurality of partitioning structures that partition the interior space of the magazine into a plurality of slots that are each capable of accommodating at least one data cartridge; and (c) a coupling structure that allows the box structure to be attached/detached to/from an entry/exit port structure. In one embodiment, the coupling structure is comprised of a first substantially rigid flange that extends away from a first side wall portion and a second substantially rigid flange that extends away from a second side wall portion that is separated from and substantially parallel to the first side wall portion. In one embodiment, the first and second flanges are located in an asymmetric manner so that the box structure can only be mounted to the entry/exit port structure in a particular orientation.

[0023] The present invention further provides a data cartridge library with an entry/exit port that has a frame that can be readily attached and detached to facilitate maintenance of the entry/exit port. In one embodiment, the library is comprised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine; (c) a drive; and (d) a transport assembly that is capable of moving a data cartridge between any

one of the plurality of magazine data cartridge storage spaces and the drive. The library is further comprised of an entry/exit port for moving entry/exit port magazines between an exterior environment and an interior environment of the library where the magazine is accessible to the transport device. In one embodiment, the entry/exit port comprises a mount to which a magazine can be attached and from which a magazine can be detached, a guide structure for constraining the movement of the mount between a first position at which a user can attach/detach a magazine to/from the mount and a second position at which the transport assembly is capable of inserting/removing a data cartridge into/from a magazine attached to the mount, and a motive device for providing the motive force for moving the mount between the first and second positions. The entry/exit port further comprises a "stop" structure that is attached to the mount and operates to prevent the mount from being moved beyond the first position. A quick release structure allows the stop structure to be quickly detached from the mount so that the mount can be readily removed from the library.

[0024] The present invention also provides a data cartridge library with a drive bay that is capable of accommodating a

full-height drive and being altered to accommodate two, half-height drives. In one embodiment, the library is comprised of: (a) a frame/chassis/cabinet; (b) a data cartridge magazine; and (c) a transport assembly that is capable of moving a data cartridge between any one of the plurality of magazine data cartridge storage spaces and any one of the drives within the library. The library is further comprised of a drive bay that provides a full-height drive space that is capable of accommodating a full-height drive and a partition mount for supporting a partition that allows the full-height drive space to be divided into two, half-height drive spaces that are each capable of accommodating a half-height drive. In one embodiment, the full-height drive space is capable of: (a) accommodating a full-height drive that is located within a full-height drive sled; or (b) when a partition engages the partition mount, accommodating two, half-height drives that are each located within a half-height drive sled. In other embodiments, the library is further comprised of combinations of full-height and half-height drives located in the drive bay.

[0025] The present invention also provides a data cartridge library with a universal bay that is capable of accommodating one or more electronic devices that are not necessary

to the operation of the library but can be used to enhance or supplement the operation of the library. In one embodiment, the library is comprised of a frame/chassis/cabinet that defines an interior space. The interior space is partitioned into: (a) a data cartridge space that provides storage locations for all of the cartridges that the library is capable of storing; (b) a drive space that provides locations for all of the drives that the library is capable of supporting; (c) a transport assembly space for accommodating the movement of a picker and elevator in moving a data cartridge between any one of the data cartridge storage locations and any one of the drives within the library; (d) a power supply space for housing all of the power supplies that the library is capable of supporting; and (e) circuitry space for housing circuitry that is used to distribute power within the library and control the operation of the transport assembly. The library is further comprised of a universal bay that defines a universal space which can be used to house circuitry other than the circuitry located in the circuitry space and does not comprise any of the other noted spaces. In one embodiment, the universal bay comprises a partition mount that is capable of supporting a partition that is used to divide the universal space into

subsidiary spaces, each capable of accommodating circuitry that enhances or supplements the operation of the library.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

- [0026] Figs. 1A–1B illustrate the exterior of an embodiment of a data cartridge library that is capable of processing LTO tape cartridges;
- [0027] Fig. 2 is an exploded view of the embodiment of the data cartridge library illustrated in Figs. 1A–1B;
- [0028] Figs. 3A–3B illustrates an LTO tape data cartridge;
- [0029] Figs. 4A–4B illustrate a DLT tape data cartridge;
- [0030] Figs. 5A–5B illustrate a displaceable portion of the side of the housing of library shown in Figs. 1A–1B that allows a user to access the interior of the library;
- [0031] Figs. 6A–6C illustrate an entry/exit port associated with the data cartridge library illustrated in Figs. 1A–1B;
- [0032] Figs. 7A–7F illustrate a cartridge magazine that can be attached/detached to/from the entry/exit port illustrated in Figs. 6A–6C and portions of the magazine;
- [0033] Figs. 8A–8E illustrate a multi-piece magazine for storing a plurality of LTO tape cartridges and that is associated with the library shown in Figs. 1A–1B;

[0034] Figs. 9A–9F illustrate a drive bay that is associated with the library shown in Figs. 1A–1B and capable of accommodating multiple full-height drives and be adapted to accommodate half-height drives within a space that is capable of accommodating one of the full-height drives;

[0035] Figs. 10A–10B illustrate the space within the library shown in Figs. 1A–1B that is used to house power supplies and circuitry for distributing electrical power to various power consuming components within the library;

[0036] Figs. 11A–11C a universal bay that is associated with the library shown in Figs. 1A–1B and capable of accommodating circuitry that enhances or supplements the operation of the library but is not necessary to the operation of the library;

[0037] Figs. 12A–12F illustrate the transport system that is associated with the library shown in Figs. 1A–1B;

[0038] Fig. 13A–13B illustrates aspects of the robotics module that can be readily inserted into and removed from the library illustrated in Figs. 1A–1B;

[0039] Figs. 14A–14F illustrate the picker that is associated with the library shown in Figs. 1A–1B;

[0040] Figs. 15A1–15D2 illustrate the operation of the picker in grasping an LTO tape cartridge; and



[0041] Figs. 16A–16D illustrate the ranges of rotation of the crank during which the grasper assembly is in the open position and in the closed position.

#### **DETAILED DESCRIPTION**

[0042] With reference to Figs. 1A, 1B and 2, an embodiment of a data cartridge library 100 (hereinafter referred to as "library 100") is described. Generally, the library is comprised of: (a) a frame/chassis/cabinet 102 that defines an interior space for containing the other components of the library; (b) entry/exit port 104 for moving data cartridges into and out of the library; (c) a magazine structure 106 for providing a plurality of data cartridge storage spaces that are each capable of accommodating at least one data cartridge; (d) a drive bay 108 for housing a plurality of drives; (e) a plurality of drives 110 located in a drive bay 108, with each drive capable of writing/reading data onto/from a recording medium located in a cartridge; (f) a transport system 112 for moving a data cartridge between any one of the data cartridge storage spaces provided by the magazine structure 106 and any one of the drives 108; (g) a power supply/control module bay 114 for housing at least one power supply and control circuitry that is deemed necessary to the operation of the library; (h) a pair of

power supplies 116A, 116B that are each located in the power supply/control module bay 114; (g) a library control module 118 located in the power supply/control module bay 114; and (h) a universal bay 120 for housing electronic circuitry that enhances or supplements the operation of the library but is not deemed necessary to the operation of the library.

[0043] Before describing the library 100 in greater detail, the data cartridges that the library 100 is adapted to manipulate are described. The library 100 is adapted for operating on magnetic tape cartridges. Specifically, the library 100 is adapted for operating on cartridges that conform to the following cartridge formats: (a) LTO (linear tape open) and (b) DLT (digital linear tape). It should, however, be appreciated that the library 100 can be adapted to operate on magnetic tape cartridge that conform to other cartridge formats, such as AIT (advanced intelligent tape), SAIT (super advanced intelligent tape), Travan, and the like. Further, it should be appreciated that the library can be adapted to operate on cartridges that contain other types of recording mediums, such as magnetic disk, optical disk and optical tape mediums.

[0044] With reference to Figs. 3A–3B, an LTO tape cartridge 130

comprises a first cartridge face 132A, a second cartridge face 132B, a first cartridge side 134A, a second cartridge side 134B, a first cartridge end 136A, and a second cartridge end 136B. The distance between the first and second cartridge faces 132A, 132B defines the height of the cartridge, which is 0.85 in. The distance between the first and second side surfaces 134A, 134B defines the width of the cartridge, which is 4.15 in. The distance between the first and second ends 136A, 136B defines the depth of the cartridge, which is 4.02 in. The cartridge further comprises an orientation feature 138 that provides a basis for properly orientating the cartridge for insertion in to an LTO tape drive so that data can be read from and/or written to the recording medium within the cartridge. The orientation feature 138 also provides a basis for orienting all of the LTO tape cartridges stored within the library 100 in the same manner. The cartridge also comprises a first pair of gripper notches 140A, 140B and a second pair of gripper notches 142A, 142B, with one or both pair of notches typically used by a device that grips the cartridge during transport between a magazine and a drive.

[0045] With reference to Figs. 4A–4B, a DLT tape cartridge 150 comprises a first cartridge face 152A, a second cartridge

face 152B, a first cartridge side 154A, a second cartridge side 154B, a first cartridge end 156A, and a second cartridge end 156B. The distance between the first and second cartridge faces 152A, 152B defines the height of the cartridge, which is 1.00 in. The distance between the first and second side surfaces 154A, 154B defines the width of the cartridge, which is 4.15 in. The distance between the first and second ends 156A, 156B defines the depth of the cartridge, which is 4.16 in. The cartridge further comprises an orientation feature 158 that provides a basis for properly orientating the cartridge for insertion into a DLT tape drive so that data can be read from and/or written to the recording medium within the cartridge. The orientation feature in an actual DLT is somewhat more complex than the feature shown in Fig. 4A. The orientation feature 158 also provides a basis for orienting all of the DLT tape cartridges stored in the library 100 in the same manner. The cartridge also comprises a single gripper notch 160, which is typically used by a device that grips the cartridge during transport between a magazine and a drive. The DLT tape cartridge 150 further comprises a recess 162 in the first end 156A that is typically used for to hold a label, such as a bar-code label, that is used to identify the car-

tridge.

[0046] Having described the tape data cartridges on which the library 100 operates, the library 100 is now described in greater detail. With reference to Figs. 1A–1B, the library 100 comprises a front side 170A, a rear side 170B, a first lateral side 170C, a second lateral side 170D, a top side 170E, and a bottom side 170F.

[0047] Associated with the front side 170A of the library 100 is the entry/exit port 104 and a power button 172 that allows a user to control the application of electrical power from the power supplies 116A, 116B to components of the library. Also associated with the front side 170A is a touch screen 172 that is used to output information relating to the library 100 to a user and to allow a user to input information (e.g., commands) to the library 100. Other types of input and output peripherals can be used in place of the touch screen 106. For instance, a screen can be provided to output information to a user and a keyboard can be provided to allow a user to input information. A front panel 176 that provides ports for accommodating the entry/exit port 104, the power button 172 and the touch screen 172 is also associated with the front side 170A. The front panel 176 is also capable of being re-

moved by a user to allow the user to access the interior of the library 100.

[0048] Associated with the rear side 170B of the library 100 is access to the space within the drive bay 108, which allows a user to insert/remove a drive into/from the drive bay 108. User access to the power supply / control module bay 114 is also associated with the rear side 170B. Specifically, a user can insert/remove a power supply and/or insert/remove a library control module via the access provided to the power supply / control module bay 114 at the rear side 170B. Also associated with the rear side 170B is access to the space within the universal bay 120. In the embodiment of the library illustrated in Fig. 1B, a pair of quad-interface processors are resident in the space defined by the universal bay 170B.

[0049] The first lateral side 170C comprises a cosmetic exterior skin 178A. Underlying the skin 178A is: (a) a side portion 180A of a top tray 182, (b) a side portion 184A of a bottom tray 186, and (c) portions of the magazine structure 106 that connect the side portion 180A and the side portion 184A. The side portion 184A also accommodates a rail that facilitates rack mounting of the library 100. Similarly, the second lateral side 170D comprises a cosmetic

exterior skin 178B. Underlying the skin 178B is: (a) a side portion 180B of a top tray 182, (b) a side portion 184B of a bottom tray 186, and (c) portions of the magazine structure 106 that connect the side portion 180B and the side portion 184B. The side portion 184B also accommodates a rail that facilitates rack mounting of the library 100.

[0050] The top side 170E comprises a mid-portion 188 of the top tray 182 that extends between the side portions 180A, 180B. Similarly, the bottom side 170F comprises a mid-portion 190 of the bottom tray 186.

[0051] The top tray 182, bottom tray 186, and the portions of the magazine structure 106 that connect the top tray 182 and the bottom tray 186 form the frame 102, i.e., the structure that supports the other elements of the library and defines an interior space in which the other elements of the library reside. It should be appreciated that other frame structures are also feasible.

[0052] With reference to Figs. 5A–5B, the removable front panel 176 is described in greater detail. Generally, the removable front panel 176 comprises a panel structure 200 and a plurality of captured screws 202, i.e. screws that can be actuated to attach/detach the front panel 176 from the

remainder of the library 100 but that remain attached to the panel structure 200 to prevent loss. A plurality of threaded holes 204, each for engaging one of the captured screws 202, are associated with portions of the library other than the front panel 176. When the front panel 176 is in place, as shown in Fig. 1A, each of the captured screws 202 is accessible to a user and engages one of the threaded holes 204, thereby placing the front panel 176 in a "closed" state that prevents a user from accessing the interior of the library 100 via the opening covered by the front panel 176. If a user wants to access the interior of the library 100, the captured screws 202 are actuated to disengage the screws from the threaded holes. After all of the captured screws 202 have been disengaged from the threaded holes 204, the front panel 176 can be removed to expose the interior of the library. The opening provided by removal of the front panel 176 is sufficient to allow a transport module comprised of a picker and a substantial portion of an elevator and an associated tray to be inserted/removed into/from the interior of the library 100. The front panel 176 also defines openings 206A–206C that respectively accommodate the exit/entry port 104, the power button 172, and the touch screen 174.



[0053] With reference to Fig. 5B, the front panel 176 is comprised of a sheet metal portion 208 and a plastic portion 210 that is readily attached/detached to/from the sheet metal portion 208 to expose at least some of the captured screws 202. The sheet metal portion 208 supports all of the captured screws 202. Additionally, the sheet metal portion 208 is comprised of: (a) a first screen portion 212 that allows air to flow from the exterior environment into the interior of the library to cool components located therein but prevents electro-magnetic radiation from escaping from the interior of the library; (b) a second screen portion 214 that permits a user to view the interior of the library when the front panel is in the closed state but prevents electro-magnetic radiation from escaping from the interior of the library; (c) openings 216A–216C that respectively form portions of the openings 206A–206C; (d) locator pin holes 218A–218C that cooperate with locator pins that are associated with the plastic portion 210 to facilitate the mating of the plastic portion 210 to the sheet metal portion 208; and (e) socket portions 220A–220D of ball-and-socket clips (aka Tinneman clips) that are used to attach/detach the plastic portion 210 to the sheet metal portion 208.

[0054] The plastic portion 210 comprises: (a) a window 222 that, when the plastic portion 210 is properly mated with the sheet metal portion 208, is located adjacent to the second screen portion 214 of the sheet metal portion 208; (b) openings 224A–224C that cooperate with the openings 216A–216C to form the openings 206A–206C when the plastic portion 210 is properly mated with the sheet metal portion 208; (c) locator pins 226A–226C that cooperate with the locator pin holes 218A–218C to facilitate alignment of the plastic portion 210 with the sheet metal portion 208 when mating the plastic portion 210 to the sheet metal portion; (d) balls 228A–228D for engaging the sockets 220A–220D associated with the sheet metal portion 208 to facilitate attachment/detachment of the plastic portion 210 to/from the sheet metal portion 208.

[0055] With reference to Figs. 6A–6C, the entry/exit port 104 is of a type that moves a magazine frame or mount between an "open" position, as shown in Fig. 6A, and a "closed" position as shown in Fig. 1A. When the magazine frame is in the "open" position, a user can attach a magazine to the magazine frame. Further, if a magazine is attached to the magazine frame and the magazine frame is in the open position, a user can insert a data cartridge into the library

by placing a data cartridge in one of the slots of the magazine (either before or after the magazine is attached to the magazine frame) and then causing the magazine frame to move to the "closed" position. After the magazine frame is in the "closed" position, the data cartridge is accessible to the transport assembly. Consequently, if desired, the transport assembly can be used to move the data cartridge to any space within the library that is accessible to the transport assembly and capable of storing the data cartridge. One advantage of employing a magazine is that the magazine can be populated with multiple data cartridges, thereby allowing multiple data cartridges to be loaded into the library at one time.

[0056] If, on the other hand, a magazine is attached to the magazine frame and a user wants to remove a data cartridge from the library, the magazine frame is placed in the "closed" position. If the desired data cartridge is not already in the magazine, the transport assembly is used to move the desired data cartridge to the magazine. After the desired data cartridge is loaded into the magazine, the magazine frame is caused to move from the "closed" position to the "open" position so that the user can remove the desired data cartridge from the magazine. One advan-

tage of employing a magazine is that multiple data cartridges can be removed from library at one time, either by removing the cartridges from the magazine or disengaging the magazine from the frame.

[0057] With reference to Figs. 6A–6C, the entry/exit port 104 is comprised of: (a) a magazine frame 240; (b) a guide structure 242 for supporting the magazine frame 240 and guiding the magazine frame between "open" and "closed" positions; (c) a drive mechanism 244 for applying a motive force to the magazine frame 240 to drive the magazine frame between the "open" and "closed" positions; and (d) a sensor system 246 for use in determining when the magazine frame 240 is in the "open" position and when the magazine frame is in the "closed" position.

[0058] With continuing reference to Figs. 6B–6C, the magazine frame 240 is comprised of: (a) a top guide channel 248; (b) a bottom bracket 250; (c) a front side bracket 252 that is attached to the top guide channel 248 and the bottom bracket 250; (d) a back side bracket 254 that is attached to the top guide channel 248 and the bottom bracket 250; (e) a bottom rail 256 that is operatively attached to the bottom bracket 250; (f) a rack 258 that is operatively attached to the bottom bracket 250; and (g) a stop 262, op–

eratively attached to the bottom bracket 250, for preventing the drive mechanism 244 from driving the magazine frame 240 beyond the "open" and "closed" positions.

[0059] The front side bracket 252, back side bracket 254, a portion of the top guide channel 248 and a portion of the bottom bracket 250 form a magazine receptacle 264 for receiving a magazine.

[0060] Further, the front side bracket 252 and back side bracket 254 each respectively comprise a first flange engagement structure 268A and second flange engagement structure 268B that are each capable of receiving and engaging one of a pair of flanges associated with a magazine to secure the magazine within the receptacle 264. The first and second flange engagement structures 268A, 268B, if engaging the pair of flanges associated with a magazine, can also be disengaged from the flanges so that the magazine can be removed from the receptacle 264. The first and second flange engagement structures 268A, 268B are located such that the magazine can only be received in the magazine receptacle 264 when the magazine is in a particular orientation.

[0061] Also associated with the front side bracket 252 is a cover mounting bracket 270 that support a entry/exit port cover

272.

[0062] With continuing reference to Figs. 6A–6C, the guide structure 242 is comprised of a top guide structure 274 that engages the top guide channel 248. The top guide structure 274 is comprised of a bracket 276 that is attached to the exterior skin 178B and two pairs of rollers 278A, 278B that each engage a flange of the top guide channel 248 to guide the magazine frame 240.

[0063] The guide structure 242 is further comprised of a bottom guide structure 280 that engages the bottom rail 256. The bottom guide structure 280 is comprised of a bracket 282 that supports rail brackets 284A, 284B. The rail brackets 284A, 284B capture the rail 256 and allow the rail 256 to be linearly displaced so that the frame can be moved between the "open" and "closed" positions.

[0064] The drive mechanism 244 is comprised of the rack 258, a stepper motor 288 that is attached to the mounting bracket 282, a pinion 290 that is attached to the spindle of the motor 286, and a cluster gear 292 that connects the rack 258 and the pinion 290. In operation, the stepper motor 288 produces a motive force that is used to translate the magazine frame 240 between the "closed" and "open" positions. More specifically, the stepper motor 288

produces a rotational motive force that is transferred to the rack 258 via the pinion 290 and the cluster gear 292. The interaction of the cluster gear 292 and the rack 258 translates the rotation motive force into a translational motive force that is used to move the magazine frame 240 between the "closed" and "open" positions. The stepper motor 288 is capable of being controlled so as to rotate the spindle in either a clockwise direction or a counter-clockwise direction. Rotation of the motor spindle in the clockwise direction causes the magazine frame 240 to move towards the "open" position. Conversely, rotation of the motor spindle in the counter-clockwise direction causes the frame to move towards the "closed" position.

[0065] The sensor system 246 is comprised of a flag 294 that is attached to the bottom bracket 250 of the magazine frame 240, a first detector 296 for detecting when the magazine frame 240 is in the "open" position and that is attached to the mounting bracket 284B, a second detector 298 for detecting when the magazine frame 240 is in the "closed" position. The second detector 298 is supported by a bracket 300 that is attached to the side portion 184B of the bottom tray 186. In operation, the sensor system 246 detects that the magazine frame 240 is in the "open"

position when the first detector 296 detects the flag 294. Similarly, the sensor system 246 detects that the magazine frame 240 is in the "closed" position when the second detector 298 detects the flag 294.

[0066] The sensor system 246 is further comprised of a comb flag 302 and a third sensor 304 that are used to determine the position of the frame 240 when the frame 240 is located between the "open" and "closed" positions.

[0067] With continuing reference to Figs. 6A–6C, the stop 262 engages a portion of the bracket 300 to prevent the drive mechanism 244 from driving the magazine frame 240 beyond the "closed" position. The stop 262 engages the bracket 282 to prevent the drive mechanism 244 from driving the magazine frame 240 beyond the "open" position. The stop 262 is attached to the bottom bracket 250 by four screws 306. Notably, the magazine frame 240 can be disengaged from the guide structure by unscrewing the four screws 306 so that the stop 262 is no longer attached to the bottom bracket 250, thereby allowing the frame 240 to be displaced beyond the "open" position.

[0068] With reference to Figs. 7A–7F, an embodiment of a entry/exit port magazine 310 that is capable of holding a plurality of LTO tape cartridges and being engaged/disen-



gaged to/from the magazine frame 240 of the entry/exit port 104 is described. The magazine 310 is comprised of a cartridge holding portion 312 and a dust cover 314.

[0069] The cartridge holding portion 312 is comprised of a bottom wall 316 and a side wall 318 that extends from the bottom wall 316 to a side wall edge 320, which defines the opening through which an LTO cartridge is inserted/extracted into/from the magazine 310. The side wall 318 is comprised of first and second end walls 322A, 322B and first and second side walls 324A, 324B.

[0070] Respectively associated with the first and second side walls 324A, 324B are first and second frame engagement structures 326A, 326B. The first frame engagement structure 326A is comprised of a first substantially rigid flange 328A that extends outward from the first side wall 324A and a first pair of ribs 330A, 332A. Similarly, the second frame engagement structure 326B is comprised of a substantially rigid flange 328B that extends outward from the second side wall 324B and a second pair of ribs 330B, 332B. The first substantially rigid flange 328A comprises a first engagement surface 334A that is located at a first distance from the edge 320. Similarly, the second substantially rigid flange 328B comprises a second engage-

ment surface 334B that is also located at the first distance from the edge 320. The bottom edges of the first pair of ribs 330A, 332A and second pair of 330B, 332B are each located at a second distance from the edge 320 that is less than the first distance. The difference between the first and second distances is slightly greater than the thickness of the material in which the first and second flange engagement structures 268A, 268B have been established.

[0071] To engage the magazine 310 to the frame 240 of the entry/exit port 104 (assuming the port is in the "open" position), the magazine is inserted into the receptacle 264 such that the substantially rigid flanges 328A, 328B are respectively pass through the wider openings located towards the top ends of the first and second flange engagement structures 268A, 268B. The first pair of ribs 330A, 332A and the second pair of ribs 330B, 332B respectively engage the back side bracket 254 and the front side bracket 252 to limit the extent to which the flanges 328A, 328B can pass through the larger portions of the first and second flange engagement structures 268A, 268B. At this point, the magazine 310 is displaced towards the bottom bracket 250 so that the first engagement surface 334A of

the first flange 328A engages the posterior side of the back side bracket 254 and the second engagement surface 334B of the second flange 328B engages the posterior side of the front side bracket 252. At this point, the first engagement surface 334A is engaging the posterior side of the back side bracket 254 and the bottom edges of the first pair of ribs 330A, 332A are engaging the anterior surface of the back side bracket 254. Likewise, the second engagement surface 334B is engaging the posterior side of the front side bracket 252 and the second pair of ribs 330B, 332B are engaged to the anterior surface of the front side bracket 252. With the first and second engagement surfaces 334A, 334B and the bottom edges of the first and second pairs of ribs 330A, 332A, 330B, 332B engaged to the frame 240 in this manner, the position of the magazine is substantially fixed in two orthogonal dimensions. An end rib 334 associated with the first end wall 322A engages the bottom bracket 250 to limit the extent to which the magazine 310 can be displaced towards the bottom bracket 250. To disengage the magazine 310 from the frame 240 (still assuming the port 104 is in the "open" condition), the attachment operation is reversed, i.e., the magazine 310 is displaced away from the bottom bracket

250 until the first and second flanges can be pulled through the wider openings located towards the top ends of the first and second flange engagement structures 268A, 268B to disengage the magazine 310 from the frame.

[0072] The first and second substantially rigid flanges 328A, 328B are also located so as to establish an asymmetry that constrains the magazine 310 to be mounted to the frame 240 in a single, preferred orientation. To elaborate, the asymmetry is established by locating the first flange 328A such that the flange is a first distance from the first end wall 322A and locating the second flange 328B such that the flange is a second distance from the second end wall 322B that is not equal to the first distance. In the illustrated embodiment, the first flange 328A is located at a first distance from the first end wall 322A and a second distance from the second end wall 322B that is different than the first distance, and the second flange 328B is located the same second distance from the second end wall 322B. In addition, a cut-out 249 associated with the top guide channel 248 and the lack of a comparable cut-out associated with the bottom bracket 252 prevent the magazine 310 from being mounted to the frame 240 in an un-

desired orientation.

[0073] Associated with the bottom wall 316 are a plurality of holes 336A–336D that are each engaged by a protrusion on the dust cover 314 of another magazine 310 to facilitate stacking of the magazines. There are numerous alternatives to the holes 336A–336D. Among the possible alternatives are: (a) one or more recesses that are each adapted to engage a protrusion on the dust cover of another magazine; and (b) one or more protrusions that are each adapted to engage a hole on the dust cover of another magazine. Different numbers of structures can be utilized. Moreover, a structure with a different shape than the holes 336A–336D is also feasible.

[0074] With reference to Figs. 7A, 7B, and 7D, the dust cover 314 comprises an exterior surface 338 and an interior surface 340. Associated with the exterior surface are protrusions 342A–342D that are each capable of mating with one of the plurality of holes 336A–336D associated with another magazine to facilitate stacking of the magazines. There are numerous alternative structures to the protrusions 342A–342D that can be used to facilitate stacking of magazines. For instances, holes or recesses that mate with protrusions located on the bottom wall of a magazine

can be used in place of the protrusions 342A–342D. Different numbers of structures and/or structures with different shapes from those illustrated can also be utilized.

[0075] Associated with the interior surface 340 of the cover 314 are a first pair of detents 344A, 344B and a second pair of detents 346A, 346B that are used to fasten the cover 314 to the cartridge holding portion 312. To elaborate, the first pair of detents 344A, 344B are adapted to engage a portion of a lip that is associated with the edge 320 and that is located adjacent to first flange 328A, and the second pair of detents 346A, 346B are adapted to engage a portion of the lip that is located adjacent to the second flange 328B. A pair of tabs 348A, 348B allow a user to disengage the cover 314 from the cartridge holding portion 312. To elaborate, the first tab 348A allows a user to flex the cover 314 (which is preferably made of plastic) adjacent to the first pair of detents 344A, 344B in a manner that disengages the first pair of detents 344A, 344B from the lip. The second tab 348B similarly allows a user to disengage the second pair of detents 346A, 346B from the lip.

[0076] Respectively associated with the first and second end walls 322A, 322B are first and second bar code areas

350A, 350B that are each capable of accommodating a bar code. In many cases, the bar code is imprinted on a label that is placed in the bar code area. In some embodiments, a single bar code area that is associated with one of the first and second end walls 322A, 322B or one of the first and second side walls 324A, 324B is adequate. In other embodiments, two or more bar codes areas, each associated with one of the first and second end walls 322A, 322B and the first and second side walls 324A, 324B is needed or desirable.

[0077] Extending from the second end wall 322B is a third bar code area 350C, which is shown with a bar code label attached. The third bar code area is located so that when the magazine 310 is within the library, the magazine can be identified. To elaborate, when the magazine 310 is attached to the magazine frame 240, any bar codes associated with the first and second bar code areas 350A, 350B or associated with any other locations on the side wall 318 are likely to be difficult for a bar code reader associated with the transport system 112 to read. In contrast, a bar code associated with the third bar code area 350C is readily visible to such a bar code reader. Generally, any bar code associated with the third bar code area 350C is

identical to the bar code associated with the first and second bar code areas 350A, 350B. However, it is not required that a bar code associated with an individual magazine be identical to any other bar codes associated with the magazine.

[0078] With reference to Figs. 7E and 7F, the bottom wall 316, the first and second end walls 322A, 322B, the first and second side walls 324A, 324B define an interior space that is capable of accommodating a plurality of the LTO tape cartridges. In the illustrated embodiment, three LTO cartridges are shown located within the interior space of the magazine 310. A plurality of partition structures 352 divide the interior space into a plurality of data cartridge storage spaces 354, each being capable of accommodating a single LTO tape cartridge. Each partition 352 is comprised of a pair of panels 356A, 356B and a pair of spacer ribs 358A, 358B. The spacer ribs 358A, 358B serve to space cartridges that are stored in adjacent storage spaces a sufficient distance from one another so that the picker associated with the transport assembly can grasp one of the cartridges without interference from any adjacent cartridges. Associated with each of the storage space 354 is a pair of centering fins 360A, 360B that serve to



center a data cartridge within the storage space.

[0079] Also associated with each storage space 354 is an orientation structure 362 that prevents insertion of an LTO tape cartridge into space if the cartridge does not have the proper orientation. To elaborate, the orientation structure 362 is designed to accommodate or complement the orientation feature 138 of an LTO tape cartridge that is being inserted into the space and has the desired orientation. If, however, an LTO tape cartridge is being inserted into the space and does not have the desired orientation, the orientation structure 362 is not positioned to accommodate the orientation feature 138 of the LTO tape cartridge and, as such, interferes with the insertion of the LTO tape cartridge into the space. Further, all of the orientation structures 362 in the magazine 310 are substantially identical to one another and in substantially the same location in each storage space. Consequently, the orientation structures cumulatively operate to ensure that all of the cartridges that can be held by the magazine have the same orientation within the magazine. This characteristic of the magazine, in combination with the features of the magazine that require the magazine to be in a specific orientation for attachment to the magazine frame

240 of the entry/exit port 104, ensure that all of the data cartridge that are placed in the library via the entry/exit port 104 have the same orientation relative to the picker, which facilitates the design of the picker.

[0080] Additionally, a retaining structure 364 is associated with each of the storage spaces 354 to prevent unintentional dislodgement of an LTO cartridge located in the space. Generally, the retaining structure comprises a cantilever member with one end fixed to the cartridge holding portion 312 and a free or movable end that supports a detent for engaging the notch 142B of an LTO cartridge. In operation, the spring force provided by the cantilever member urges the detent into engagement with the notch 142B during insertion of the LTO cartridge into the cartridge holding portion 312 and allows the detent to disengage from the notch during extraction of the cartridge by a picker or user.

[0081] Each of the storage spaces 354 also comprises portions of stand-offs 366A, 366B that ensure that the cartridge end 136A of the LTO cartridge is substantially the same distance from the bottom wall of the 316 of the magazine 310 as the cartridge end 156A of a DLT tape cartridge is from the bottom wall of a magazine designed to accom-

modate DLT tape cartridges. In libraries that are capable of operating on cartridges with different dimensions, such as library 100, the use of stand-offs to ensure this consistency of cartridge location simplifies the picker design.

[0082] Associated with the side wall 324A are two orientation surfaces 368A, 368B that can each be used by a picker to locate the data cartridge storage spaces 354. The cover 314 is designed to accommodate the orientation surfaces 368A, 368B.

[0083] Associated with the side wall 324B are blockers 369A, 369B that serve to prevent the magazine frame 240 of the entry/exit port 104 from reaching the closed position, as shown in Fig. 1A, if the magazine 310 is not fully engaged to the frame 240.

[0084] Associated with one of the partitions 352 is a strut 370 that connects the pair of panels 356A, 356B. The strut 370 prevents the first and second side walls 324A, 324B from bowing towards or away from one another. A picker space 372 associated with the storage space 254 immediately adjacent to the first end wall 322 provides space that is utilized by a picker in inserting a data cartridge into the space 254 and retracting a data cartridge from the space 254.

[0085] With reference to Figs. 2 and 8A–8E, the magazine structure 106 comprises first and second banks of magazines 380A, 380B. The first bank of magazines 380A is described with the understanding that the second bank of magazines 380B (other than accommodating the entry/exit port 104) is substantially identical. The first bank of magazines 380A is comprised of four, multi-piece magazines 382A–382D. With reference to Fig. 8A, each of the multi-piece magazines 382A–382D is comprised of a back side 384, a first side 386A, and a second side 386B that cumulatively define an interior space for accommodating a plurality of data cartridges and an opening through which data cartridges can be inserted/extracted into/from the interior space. Each of the multi-piece magazines 382A–382D also comprises a partitioning structure 388 that divides the interior space into a plurality of storage spaces that are each capable of accommodating an LTO tape data cartridge.

[0086] With reference to Figs. 8A–8E, each of the multi-piece magazines 382A–382D is comprised of a C-channel 390 and at least one magazine clip 392. The C-channel 390 forms substantially the entire back side 384 of the magazine and portions of the first and second sides 386A,

386B of the magazine. The C-channel 390 comprises first and second C-channel sides 394A, 394B and a C-channel mid-section 396 that extends between and connects the first and second C-channel sides 394A, 394B. The C-channel mid-section 396 forms substantially the entire back side 384 of the magazine. In addition, the C-channel mid-section 396 comprises a plurality of stand-offs 398, with each stand-off positioned to engage at least one LTO tape cartridge located in one of the storage spaces provided by the magazine such that the cartridge end 136A of the LTO cartridge is substantially the same distance from the back side 384 as the cartridge end 156A of a DLT tape cartridge is from the back side 384 of a magazine designed to accommodate DLT tape cartridges. In libraries that are capable of operating on cartridges with different dimensions, such as library 100, the use of stand-offs to ensure this consistency of cartridge location simplifies the picker design. The C-channel mid-section 396 further comprises a plurality of rivet holes 400 that allow the C-channel 390 to be attached to the top tray 182, bottom tray 186, and exterior skins 178A, 178B by rivets. The C-channel 390, in connecting the top tray 182 and the bottom 186 to one another, also provides struc-

tural support that is not provided by the exterior skins 178A, 178B. Consequently, each of the C-channels forms a structural portion the frame 102.

[0087] Respectively associated with the first and second C-channel sides 394A, 394B are first latch elements 402A, 402B that each form a latch with a second latch element associated with the magazine clip 392 to join the magazine clip and the C-channel 390. In the illustrated embodiment, the first latch elements 402A-402B are holes.

However, other types of latch elements are feasible. A plurality of slits 404 are also associated with each of the first and second C-channel sides 394A, 394B. The slits 404 cooperate with slot defining structures that are associated with the magazine clip 392 to further fix the magazine clip 292 to the C-channel 390 in the manner that slotted cards are interconnected to build a house of cards.

[0088] The C-channel 390 is preferably made of a metal (aluminum, sheet steel etc.). Further, the C-channel of each of the magazines in the first bank of magazines 380A forms a portion of the frame 102 of the library 101. This is also the case with respect to the second bank of magazines 380B with the possible exception of the magazine situation above the entry/exit port 104.

[0089] The magazine clip 392 is comprised of a side wall 406 that extends from a bottom edge 408 to a top edge 410 that defines an opening through which an LTO cartridge is inserted/extracted into/from the magazine when the magazine clip 392 is joined to the C-channel 390. The side wall 406 is comprised of first and second end walls 412A, 412B and first and second side walls 414A, 414B. Associated with the first and second side walls 414A, 414B are second latch elements 416A–416B that respectively cooperate with first latch elements 402A–402B of the C-channel 390 to connect the magazine clip 392 and the C-channel 390. In the illustrated embodiment, the second latch elements 416A–416B are each substantially rigid flanges. In joining the magazine clip 392 to the C-channel 390, the magazine clip 392 are brought together such that the second latch elements 416A, 416B cause the first and second C-channel sides 394A, 394B to flex or spread apart. Once, however, the second latch elements 416A, 416B reach the first latch elements 402A, 402B, the first and second C-channel side 394A, 394B come together to latch the magazine clip 392 and the C-channel 390.

[0090] Also associated with the first and second side walls 414A,

414B are slot defining structures 418 that are each adapted to engage one of the slits 404 associated with the first and second C-channel sides 394A, 394B. The slot defining structures 418 and slits 404 operate to prevent the magazine clip 392 from being displaced towards the top tray 182 or the bottom tray 186.

[0091] The magazine clip 392 further comprises a plurality of partitions 420 that define a plurality of LTO tape cartridge storage spaces 422. Each of the partitions 420 is comprised of a panel 424, pair of spacer ribs 426A, 426B that are each substantially identical to the comparable element associated with the entry/exit port magazine 310 and perform substantially the same function as the comparable element of the entry/exit port magazine 310. As such, these elements will not be described further. Associated with each of the storage spaces 422 are centering fins 428A, 428B and a retaining structure 430, which are each substantially identical to the comparable element associated with the entry/exit port magazine 310 and perform substantially the same function as the comparable element in the magazine 310. Consequently, these features will not be described further.

[0092] Notably, the magazine clip 392 does not include any kind



of orientation feature for ensuring that cartridges held by the magazine have a predetermined orientation. The magazine clip 392 lacks an orientation feature because it is assumed that substantially all of the data cartridges that will be held by any one of the magazine associated with the first and second banks of magazines 380A, 380B will enter the library via the entry/exit port 104 and, as such, will have the desired predetermined orientation due to the operation of the entry/exit port 104 and the entry/exit port magazine 310.

[0093] The magazine clip 392 also does not have any kind of back wall or stand-off feature like the entry/exit port magazine 310, nor does it need any of these features because these features are provided by the C-channel 390. Consequently, absent the operation of the retaining structure 430 associated with each data cartridge storage space of the magazine clip 392 and the attachment of the clip 392 to the C-channel 390, a data cartridge can be passed all the way through the magazine clip 392. For example, a data cartridge could be inserted into the magazine clip 392 through the opening defined by the top edge 410 and, absent the operation of the retaining structure, be extracted through an opening defined, at

least in part by the bottom edge 408.

[0094] The magazine clip 392 is made of one of the same class of materials as is used to make the cartridge housing of a data cartridge. Consequently, at present, the magazine clip 392 is made of plastic. The use of plastic to make the magazine clip 392 results in less wear and tear on the cartridge housings over numerous insertions and extractions relative to a clip made of, for example, metal.

[0095] For cartridges with dimensions that would place the cartridge end at a different distance from the back side 384 of a magazine designed to accommodate LTO cartridges, such as magazine 382A, there are at least two possible ways to design the magazine so that the cartridge will be at the same distance from the back side and thereby facilitate the picker design. First, a shim can be attached to the stand-offs 398. Second, the magazine clip can be designed to hold the cartridge at the desired distance.

[0096] It should be appreciated that a multi-piece magazine can be realized in which one piece forms at least a portion of the back of the magazine that does not have a C-shape or U-shape. For example, a multi-piece magazine can be realized in which a substantially flat piece of material forms at least a portion of the back of the magazine. Addition-

ally, a multi-piece magazine can be realized in which a piece that forms at least a portion of the back of the magazine and a piece that forms at least portions of the side are attached to one another in a manner that does not involve overlapping side portions provided by each of the pieces. For example, the pieces can be joined to one another with a connector that forms a butt joint between the pieces.

[0097] With reference to Figs. 9A–9F, the drive bay 108 is comprised of a frame 442 that defines a drive bay space which is capable of accommodating a number of LTO drives that are each contained within a drive sled that facilitates hot-swapping of drives to and from the library 100. The frame 442 defines a first opening 444 (see Fig. 2) that exposes any drives appropriately located in the drive bay 108 so to the transport system 112 can load and unload tape cartridges from the drive. The frame 442 also defines a second opening 446 that allows a user to insert and remove drives from the drive bay space.

[0098] With reference to Fig. 9B, which is a cross-sectional view of the drive bay 108, the drive bay 108 is further comprised of five fixed-partitions 448A–448E that divide the drive bay space into six, full-height drive spaces

450A–450F, each capable of accommodating a full-height LTO drive located in a drive sled. The portion of the frame 442 adjacent to each of the full-height drive spaces 450A–450F defines a pair of slots 452A, 452B that are capable of engaging an insertable/removable partition 454. If the partition 454 engages one of the pair of slots 452A, 452B, the full-height drive space with which the pair of slots is associated is divided into two, half-height drive spaces 456A, 456B, each capable of accommodating a half-height drive located within a drive sled. Consequently, the drive bay 108 can be configured to provide twelve half-height drive spaces. However, because of the operation of the transport assembly 112, the upper-most and lower-most half-height drive spaces cannot be utilized. As a consequence, only the middle ten of the twelve possible half-height drive spaces can be utilized. In libraries that employ different transport assemblies and/or have different dimensions, this constraint on the number of half-height drives may not be present and, as such, all of the possible half-height drive spaces will be capable of being utilized.

[0099] Associated with each of the full-height drive spaces 450A–450F are first and second plugs 458A, 458B that

are used to provide power and intra-library control via a controller area network (CAN) to a full-height drive located in the space. If a full-height drive space is divided into two, half-height drive spaces, the first plug 458A is used to provide power to any half-height drive located in the half-height drive space 456A (i.e., the upper, half-height drive space) and the second plug 458B is used to provide power to any half-height drive located in the half-height drive space 456B (i.e., the lower, half-height drive space).

[0100] As should be appreciated, the drive bay 108 is capable of accommodating only full-height drives, only half-height drives, combinations of full-height and half-height drives, and less than a full complement of drives. For example, Fig. 9C shows the drive bay 108 configured such that the full-height drive space 450B has been partitioned into two, half-height drive spaces with one space containing a half-height drive and the other space containing a half-height drive block-off plate; a full-height drive in full-height drive space 450F; and full-height drive block-off plates 460 in each of full-height drives spaces 450A, 450C, 450D and 450E.

[0101] Figs. 9D–9F illustrate a drive sled 470 for housing a full-

height LTO tape drive 472. The LTO tape drive 472 is shown with an LTO tape cartridge 474 inserted in the receptacle of the drive. The drive sled 470 generally facilitates the insertion/removal of a drive into/from the drive bay 108 via the second open side 446 of the drive bay 108. More specifically, the drive sled 470 facilitates insertion of a drive by allowing a power connection to be established between the drive and one of the plugs 458A, 458B by inserting the drive and the sled into one of the full-height drive spaces 450A–450F. The drive sled 470 facilitates removal of a drive by allowing a power connection between a drive and one of the plugs 458A, 458B to be terminated by extracting the sled from the full-height drive space 450A–450F in which the drive and sled are resident.

[0102] The sled 470 comprises a housing 476 with a front side 478A, back side 478B, first lateral side 478C, second lateral side 478D, top side 478E and bottom side 478F. Associated with the front side 478A are first and second plug receptacles 480A, 480B that are adapted to engage the plugs 458A, 458B associated with a full-height drive space within the drive bay 108.

[0103] Associated with the back side 478B of the housing are a

pair of SCSI connectors 484A, 484B that are respectively used to establish a "daisy chain" connection to a SCSI cable over which SCSI commands and data are transmitted to/from drives resident in the drive bay 108. Also associated with the back side 478B are: (a) a latch 486 that is used to retain the sled with a drive bay; (b) a handle 488 that facilitates the insertion and extraction of the sled 470 from the drive bay 108; (c) a grill 490 for moving air from the interior of the sled 470 to the exterior environment and thereby contribute to the cooling of any drive resident in the sled; and (d) an LED 491 that is used to provide a user with an indication of the operational status of any drive resident in the sled.

[0104] Associated with the first lateral side 478C of the sled 470 is a spring latch 492 that is activated by the latch 486 and cooperates with the frame 442 of the drive bay 108 to retain the sled within one of the drive storage spaces. The first lateral side 478C also comprises a pair of mounting holes 494A, 494B that each receive a screw that, in turn, engages a threaded hole associated with the housing of a drive to fix the drive within the sled. Similarly, the second lateral side 478D comprises mounting holes 496A, 496B that each receive a screw that, in turn, engages a threaded

hole associated with the housing of a drive to fix the drive within the sled.

[0105] The top side 478E can be detached from the remainder of the housing 476 so that a drive can be inserted/extracted into/from the interior of the sled 470. The top side 478E is detached by removing a screw 498 and sliding the top side 478E (which is captured by overlying flanges 500A–500D and underlying flanges 502A–502F extending from the first and second lateral sides) rearward.

[0106] With reference to Fig. 9F, the sled 470 comprises a fan 504 that operates to move air from the interior of the sled to the exterior environment via the grill 490. The sled further comprises a power distribution device 506 that distributes power received via one of the first and second receptacles 480A, 480B to the fan 504 and to any drive resident in the sled via a drive power connector 508. The power connector 508 is used to establish an electrical connection with the drive via a power cable that extends between the connector 508 and a power connection interface associated with the drive. Similarly, the interior sides of the SCSI connectors 484A, 484B are used to establish electrical connection with the SCSI interface of the drive via a SCSI cable.



[0107] A half-height sled has substantially the same structure as the full-height sled 470. However, the half-height sled has only one plug receptacle for receiving power from one of the plugs 458A, 458B associated with a half-height drive space.

[0108] With reference to Figs. 10A–10B, the power supply / control module bay 114 is comprised of a frame 520 that defines an interior space that accommodates a library control module and a maximum of two power supplies. Generally, the frame 520 is comprised of a portion of the frame 442 of the drive bay 108, a portion of the top tray 182, a section of the side portion 180B, a section of the side portion 184B, a portion of the bottom tray 186, a divider 522, and exterior wall 524. The exterior wall 524 defines a library control module opening 526 for insertion/extraction of a library control module into/from the interior space; a power supply opening 528 for the insertion/extraction of power supplies into/from the interior space; and plug receptacle opening 530 for accommodating the plug receptacles that receive the AC power plugs that are used to provide the power used by any power supplies in the interior space.

[0109] The bay 114 further comprises a library control module

cage 532 for receiving a library control module that is used to distribute power to other elements within the library 100 and control the operation of the library 100. Also comprising the bay 114 is a power supply cage 534 that is capable of accommodating two power supplies. The library 100 only requires one power supply to operate. Nonetheless, the bay 114 is able to accommodate two power supplies so that there is a back-up power supply available and on-line should one of the two, power supplies fail, thereby enhancing the reliability of the library 100.

[0110] Fig. 10B illustrate the power supply / library control module bay 114 fully populated, i.e. with a library control module 536 situated in the library control module cage 532 and first and second power supplies 538A, 538B located in the power supply cage 534. In addition, plug receptacles 540A, 540B are located in the plug receptacle opening 530.

[0111] With reference to Figs. 11A–11C, the universal bay 120 is generally for accommodating electronic or processing circuitry that can enhance or supplement the operation of the library 100 but is not electronic or processing circuitry that is necessary to the operation of the library, such nec-

essary circuitry being located in the power supply / library control module bay 114 or elsewhere. It should also be noted that the universal bay 120 is located in a space that is separate from the spaces dedicated to the storage of data cartridges (including the entry/exit port 104); drives; the transport of data cartridges between the space for storing data cartridges the drives, power supply, and control systems necessary to the operation of the library 100. Moreover, space within the universal bay 120 is not accessible to the transport system 112.

[0112] The universal bay 120 is comprised of a frame 550 that defines an interior space that accommodates enhancing or supplementing circuitry. Generally, the frame 550 is comprised of a portion of the frame 442 of the drive bay 108, a portion of the top tray 182, a section of the side portion 180A, a section of the side portion 184A, a portion of the bottom tray 186, and a divider 552. The frame also comprises an exterior wall 554 defines one or more openings that are adapted to receive the desired electronics. Since the desired electronics may be in a number of different forms the number of holes, the location of any holes, and the dimensions of any holes associated with the exterior wall 554 vary depending on the desired electronics. In the

illustrated embodiment, the exterior 554 defines the openings needed for a quad-interface process (QIP) and a card cage that can be used to accommodate the cards needed to realize a PC or other device within the library 100. A QIP is a device that is capable of processing, relative to the drives within the library 100, SCSI data and command signals associated with four SCSI busses. Normally, the QIP operates with respect to four, full-height drives but is capable of operating with eight, half-height drives.

[0113] Further comprising the universal bay 120 is a partition 556 that divides the interior space of the universal bay 120 into first and second spaces 558A, 558B. The partition 556 is removable. Consequently, should a user want to use more space than either the first space 558A or the second space 558B can provide, a greater amount of space is available. It should also be appreciated that partition structures are feasible that divide the interior space into a greater number of subsidiary spaces and into spaces with different dimension than those shown.

[0114] Associated with the first space 558A is a first circuit board 560A that is operatively attached to the divider 552 and adapted to engage the interface of whatever type of cir-

cuitry is located in the first space 558A. Similarly, a second circuit board 560B is associated with the second space 558B. The second circuit board 560B is operatively attached to the divider 552 and adapted to engage the interface of whatever type of circuitry is located in the second space 558B. If the partition 556 is removed or never installed to realize a space that is bigger than that provided by either of the first and second space 558A, 558B, one or more circuit boards are attached to the divider 552 and adapted to engage the interface of whatever circuitry the user chooses to locate in the space.

[0115] When the interior space of the universal bay 120 is divided into the first and second spaces 558A, 558B, there are presently the options of: (a) placing a QIP in one or both of the spaces; (b) placing a 3U high CPCI card cage in one or both of the spaces; and (c) placing a 6U high card cage in the second space 558B, which is taller than the first space 558A. Presently, when the interior space of the universal bay 120 is undivided, the space is capable of supporting a two high, 6U card cage. For example and with reference to Fig. 11B, the universal bay 120 comprises a 3U card cage 562 located in the first space 558A and a QIP cage 564 located in the second space 558B. Figure

11C illustrates the 3U card cage 562 populated with CPCI cards 566, and the QIP cage 564 housing a QIP 568. As should be appreciated, the use of the interior space within the universal bay 120 is not limited to the options described above.

[0116] It should be appreciated that the configuration and any reconfiguration of the drive bay 108 with drives and/or configuration or reconfiguration of the universal bay 120 can be accomplished entirely from the rear side 170B of the library 100, thereby avoiding any need to remove the library 100 from an equipment rack.

[0117] With reference to Figs. 12A–12E, the transport system 112 is comprised of: (a) a picker 580 that is capable of grasping a data cartridge that is located in a storage space associated with the entry/exit port 104, magazine structure 106, any one of the drives located in the drive bay 108 and displacing a grasped data cartridge towards or away from a storage space; and (b) an elevator 582 that moves the picker 580 within the library 100 so that the picker 580 can perform the noted grasping and displacing operations. Due to the layout of the entry/exit port 104, the magazine structure 106 and the drive bay 108 and the need for the elevator to move the picker between each

space associated with the entry/exit port 104, magazine structure 106 and the drive bay 108, the elevator 582 is capable of vertical and horizontal displacement of the picker 580, as well as rotation of the picker 580 about a vertical axis.

[0118] The elevator 582 comprises a picker carriage 584 that supports the picker 580. The carriage 584 is comprised of a vertical member 586, a top bracket 588 that is connected to one end of the vertical member 586, and a bottom bracket 590 that is connected to the other end of the vertical member 586.

[0119] Associated with the carriage 584 is a vertical displacement system 592 for vertically displacing to the picker 580 to a desired location between the top bracket 588 and the bottom bracket 590. The vertical displacement system 592 is comprised of: (a) a vertical linear rail 594 that is adapted to engage linear rail mounts associated with the picker 580 to guide the picker 580; (b) a vertical drive system 596 for providing the motive force to move the picker 580 to a desired location along the linear rail 594; and (c) a vertical position sensor system 598 for determining the location of the picker 580 along the linear rail 594.

[0120] The vertical drive system 596 is comprised of: (a) a lead screw 600 with first and second ends that respectively journaled to the top bracket 588 and the bottom bracket 590; (b) a lead screw pulley 602 that is attached to the lead screw 600; (c) a stepper motor 604; (d) a spindle pulley 606 that is attached to the spindle of the stepper motor 604; and (e) a timing belt 608 that connects the lead screw pulley 602 and the spindle pulley 606.

[0121] The vertical position sensor system 598 is comprised of: (a) a home sensor 610 that detects when the picker 580 is at a "home" position, which in this embodiment is adjacent to the bottom bracket 590; and (b) an encoder bar 612 that extends between the top bracket 588 and bottom bracket 590 and is used to determine the location of the picker 580 relative to the "home" position. Also associated with the vertical position sensor system 598 is a sensor that cooperates with the encoder bar 612 to provide information on the vertical position of the picker 580 relative to the "home" position.

[0122] Operation of the vertical displacement system 592 comprises using the stepper motor 604 to drive the lead screw 600 in either a clockwise direction to cause the picker 580 to be displaced along the linear rail 594 and towards the



top bracket 588 or a counter-clockwise direction to cause the picker 580 to be displaced along the linear rail 594 and towards the bottom bracket 590. The vertical sensor system 592 is used to control the stepper motor 604 so that the stepper motor 604 is operated to position the picker 580 at the desired vertical location.

[0123] To rotate the picker 580, the transport system further comprises a rotational displacement system 620 that is used to rotate the picker carriage 584 and, as a consequence, the picker 580. The rotational displacement system 620 comprises: (a) a top plate 622 and bottom plate 624 that are respectively journaled to the top bracket 588 and the bottom bracket 590 of the carriage 584 to guide the rotational movement of the carriage 584; (b) a rotational drive system 626 for providing the motive force to rotate the carriage 586 and the picker 580 to a desired rotational position relative to the top plate 622 and the bottom plate 624; and (c) a rotational position sensor system 628 for determining the rotational position of the carriage 584 and the picker 580. The rotational displacement system 620 further comprises a limiting system 630 for limiting the range of rotation of the carriage 584 and the picker 580.

[0124] The rotational drive system 626 comprises: (a) a stepper motor 632 that provides the motive force for rotating the carriage 584 and the picker 580 relative to the top plate 622 and bottom plate 624; (b) a sector gear 634 that is operatively attached to the bottom plate 624; (c) a pinion 636 that is operatively attached to the spindle of the stepper motor 632; and (d) a cluster gear 638 that is operatively attached to the bottom bracket 590 of the carriage 584 and that operates to transfer a rotational force from the pinion 636 to the sector gear 634.

[0125] The rotational position sensor system 628 comprises: (a) a flag 640 that is operatively attached to the bottom bracket 590 of the carriage 584; and (b) a detector 642 that operates to detect the flag 640 and thereby provide an indication of when the carriage 584 and picker 580 are at a "home" rotational position. Once the "home" position is detected using the flag 640 and the detector 642, the signals provided to the stepper motor to cause rotation of the carriage 584 and the picker 580 are also used to calculate the rotational position of the carriage 584 and the picker 580 relative to the "home" position.

[0126] The limiting system 630 operates to limit the rotation of the carriage 584 and the picker 580 to the approximately

180 degree range that is needed to move data cartridges between any of the storage and drive spaces within the library 100 that are capable of accommodating a data cartridge. The limiting system 630 comprises: (a) first and second hard stops 644A, 644B that are operatively connected to the bottom plate 624; and (b) member 646 that is operatively connected to the bottom bracket 590 of the carriage 584 and positioned to engage the first and second hard stops 644A, 644B to prevent rotation of the carriage 584 beyond the desired range.

[0127] Operation of the rotational displacement system 620 comprises using the stepper motor 632, pinion 636, cluster gear 638, and sector gear 634 to rotate the carriage 584 in a clockwise or counter-clockwise direction. The rotational position sensor system 628 is used to control the stepper motor 632 so that the stepper motor 632 positions the picker 580 at the desired rotational position. The limiting system 630 operates to limit the range of rotational positions at which the rotational drive system 626 can position the carriage 584 and picker 580.

[0128] The transport system further comprises a horizontal displacement system 650 for horizontally translating the picker 580. The horizontal displacement system 650

comprises: (a) a top guide system 652 for horizontally guiding the top bracket 588 of the carriage 584; (b) a bottom guide system 654 for horizontally guiding the bottom bracket 590 of the carriage 584; (c) a horizontal drive system 656 for providing the motive force to drive the carriage 586 and the picker 580 to a desired horizontal position; and (d) a horizontal position sensor system 658 for determining the horizontal position of the carriage 584 and the picker 580.

[0129] The top guide system 652 is comprised of: (a) a pair of rails 660A, 660B that are attached to the top tray 182; and (b) a roller system 662 that is comprised of a plate 664 that is fixed to the top plate 622 of the rotational displacement system 620 and a pair of rollers 666A, 666B that each engage the rails 660A, 660B. Each of the rollers 666A, 666B is pivotally attached to the plate 664.

[0130] The bottom guide system 654 is comprised of: (a) a horizontal linear rail 668 that is operatively attached to robotics module tray 670; and (b) a pair of linear rail mounts (not shown) that are operatively attached to the bottom plate 624 of the rotational displacement system and engage the horizontal linear rail 668.

[0131] The horizontal drive system 656 is comprised of: (a) a

stepper motor 672 that is attached to the robotic module tray 670 and provides the motive force for horizontally displacing the carriage 584 and the picker 580 that is attached to the carriage; (b) a bottom drive system 674 for applying a motive force to the bottom plate 624; (c) a top drive system 676 for applying a motive force to the top plate 622; and (d) a shaft 678 for transmitting a motive force from the bottom drive system 674 to the top drive system 676.

[0132] The bottom drive system 674 is comprised of: (a) drive pulley 680 that is attached to the spindle of the stepper motor 672; (b) a cluster pulley 682 that is operatively attached to the tray 670; (c) a first shaft pulley 684 that is also operatively attached to the tray 670; (d) a first timing belt 686 that extends between the drive pulley 680 and the cluster pulley 682; (e) a second timing belt 688 that extends between the cluster pulley 682 and the first shaft pulley 684; and (f) a connecting bracket 690 that connects the second timing belt 688 to the bottom plate 624. The connecting bracket 690 also incorporates a device for tensioning the second timing belt 688. Alternatively, tensioning of the second timing belt 688 can be accomplished by providing a structure for adjusting the position

of at least one of the cluster pulley 682 and the first shaft pulley 684.

[0133] The top drive system 676 is comprised of: (a) pulley 692 that is attached to the top tray 182 via a bracket 694; (b) a second shaft pulley 696 that is attached to the top tray 182 via a bracket 698; (c) a third timing belt 700 that extends between the pulley 692 and the second shaft pulley 696; and (d) a connecting bracket 701 that connects the third timing belt 700 to the top plate 622. The connecting bracket 701 also incorporates a device for tensioning the third timing belt 700. A screw connection 701A allows the plate 664 to be quickly disconnected from the top plate 622.

[0134] The shaft 678 comprises: (a) a first shaft piece 702 that is operatively connected to the cluster pulley 682; (b) a second shaft piece 704 that is operatively connected to the second shaft pulley 692; and (c) a connector 706 that is used to connect the first shaft piece 702 and the second shaft piece 704. The connector 706 comprises a first spline that is associated with the first shaft piece 702, a second spline that is associated with the second shaft piece 704, and a spline sleeve 708 that is attached to the second shaft piece 704. The spline sleeve 708, as a result

of its engagement with the second spline, is constrained such that it is not able to rotate about the second shaft piece 704 but is capable of being linearly displaced to engage and disengage the first shaft piece 702 and the second shaft piece 704. To elaborate, by sliding the spline sleeve 708 towards the first shaft 702, the spline sleeve 708 engages the spline of the first shaft piece 702 to connect the first shaft piece 702 and the second shaft piece 704. Conversely, by sliding the spline sleeve 708 away from the first shaft 702, the spline sleeve 708 disengages from the spline of the first shaft piece 702 to disengage the first shaft piece 702 and the second shaft piece 704. A collared spring structure 710 is used to bias the spline sleeve 708 towards engagement with the first shaft piece 702. Other biasing devices are feasible. Other coupling devices are also feasible. For example, the first shaft piece 702 and the second shaft piece 704 can be connected to one another and disconnected from one another using a clamping shaft coupler that utilizes a screw to adjust the diameter of a collar to engage or disengage the shaft pieces.

[0135] The horizontal position sensor system 658 comprises: (a) a home sensor 712 for sensing when the carriage 584 and

the picker 580 are at a horizontal "home" position from which other horizontal positions can be determined; (b) a coarse horizontal position sensor 714 for determining the coarse position of the carriage 584 and the picker 580; and (c) a fine horizontal position sensor 716. The coarse horizontal position sensor 714 comprises a coarse flag 718 that is operatively attached to the tray 670 and a coarse detector 720 that is operatively attached to the bottom plate 624 and that cooperates with the coarse flag 718 to determine the half of the range of possible horizontal positions in which the carriage 584 and the picker 580 are located. The fine horizontal position sensor 716 comprises a fine, crenelated flag 722 and a fine detector 724 that is operatively attached to the bottom plate 624 and that cooperates with the crenelated fine flag 722 to provide a higher resolution determination of the location of the carriage 584 and the picker 580 than provided by the coarse detector 720.

[0136] Operation of the horizontal displacement system 650 comprises using the stepper motor 672 to provide a motive force that is used to horizontally displace the carriage 584 and the picker 580 towards or away from the drive bay 108 as constrained by the top guide system 652 and



the bottom guide system 654. The motive force produced by the stepper motor 672 is transmitted to the carriage 584 via the bottom drive system 674, top drive system 676, and shaft 678. The horizontal position sensor system 658 is used to determine the current position of the carriage 584 and the picker 580 relative to the "home" position.

[0137] With reference to Figs. 14A–14F, the picker 580 is comprised of: (a) a base plate 800 that supports other elements of the picker; (b) a grasper assembly 802 that is capable of being placed in a "closed" state in which a data cartridge can be grasped and an "open" state in which a data cartridge can not be grasped; (c) a pusher plate assembly 804 that supports the grasper assembly 802 and is used in moving the grasper assembly towards and away from a location in which a data cartridge is located or may be located; and (d) a crank assembly 806 that provides the motive forces needed to place the grasper assembly 802 in the "open" or "closed" states and to move the pusher plate assembly 804.

[0138] In addition to supporting other elements of the picker, the base plate 800 also supports elements of the vertical displacement system 592 that are used to position the picker

580 at a desired vertical location. Specifically, the base plate 800 supports: (a) a pair of mounts 810A, 810B that connect the base plate 800 to the vertical linear rail 594; (b) a lead screw nut 812 that receives the lead screw 600; and (c) a vertical encoder sensor 814 that cooperates with the encoder bar 512 to provide information that is used to determine the vertical position of the picker 580. Rotation of the lead screw 600 provides a motive force that is applied to the base plate 800 via the lead screw nut 812 to move the base plate to a desired vertical location along the vertical linear rail 594.

[0139] The grasper assembly 802 is comprised of: (a) a static member 820 that has a first surface 822 for engaging one side of a data cartridge; and (b) a moving member system 824 that has a second surface 826 for engaging the opposite side of a data cartridge. The moving member system 824 is also capable of being moved between a "closed" position in which the second surface 826 and the first surface 822 are capable of grasping a data cartridge and an "open" position in which the second surface 826 and the first surface 822 are not capable of grasping a data cartridge. The grasper assembly 802 is further comprised of a bias system 828 that serves to bias the moving

member system 824 such that the second surface 826 is forced towards the "closed" position. Further comprising the grasper assembly 802 is grasper cam follower 830 that interacts with a grasper cam driver associated with the crank assembly 106 to force the moving member 824 towards the "open" position. It should be appreciated that grasping assemblies in which two moving members are used to grasp and release a data cartridge are also feasible. Further, grasping assemblies in which there is a bias system that biases one or more members that are used to grasp a data cartridge towards an "open" position are feasible. Similarly, grasper assemblies that employ a grasper cam follower that forces one or more member that are used to grasp a data cartridge towards a "closed" position are feasible.

[0140] The moving member system 824 is comprised of: (a) an upper jaw 836; (b) a jaw grip 838 that is attached to the upper jaw 836 and provides the second surface 826; (c) a mount 840; (d) a u-shaped linkage 842 that extends between the mount 840 and the upper jaw 836; and (e) a link 844 that also extends between the mount 840 and the upper jaw 836. The jaw grip 838 is typically made of rubber or some other material that provides a good grip.

The u-shaped linkage 842 and the link 844 operate to constrain the movement of the upper jaw 836 so that the second surface 826 associated with the jaw grip 838 does not rotate about an axis.

[0141] The bias system 828 is comprised of a spring 850 that is located within a hole 852 of a housing 854. One end of the spring 850 is located adjacent to a cover 856 that is attached to the housing 854. The other end of the spring 850 contacts a surface associated with the upper jaw 836. In operation, the spring 850 applies a force to the upper jaw 836 such that the second surface 826 is forced towards the "closed" position. Other types of bias systems are also feasible.

[0142] The grasper cam follower 830 is operatively attached to the upper jaw 836 and is comprised of a horizontal surface 860 and a transitional surface 862. The horizontal surface 860 interacts with the grasper cam driver associated with the crank assembly 806 to force the second surface 826 towards the "open" position, which is in opposition to the operation of the bias system 828. The transitional surface 826 interacts with the grasper cam driver associated with the crank assembly 806 so that there is a gradual transition of the second surface 826 between the

"open" and "closed" positions.

[0143] Associated with the grasper assembly 802 is a "tape-in-jaw" sensing system 868 that is comprised of a flag assembly 870 and a sensor 872. The flag assembly 870 is comprised of a spring-loaded plunger assembly 872. In operation, the plunger of the spring-loaded plunger 872 is in a first position if the grasping assembly 802 is not grasping a data cartridge. If, however, the grasping assembly 802 is grasping a data cartridge, the plunger moves to a second position. When the pusher plate assembly is at or near a fully retracted position, the sensor 872 can detect whether the plunger is in the first position or the second position. This information is used to determine which direction a crank associated with the crank assembly should be rotated. More specifically, if the grasper assembly 802 is grasping a data cartridge, the crank will be rotated in whichever direction, clock-wise or counter clock-wise, will maintain the grip on the data cartridge. If, the grasper assembly 802 is not grasping a data cartridge, the crank will be rotated in the opposite direction from that used to maintain a grip on a data cartridge.

[0144] The pusher plate assembly 804 is comprised of: (a) a first member 880 that supports the gripper assembly 802 and

comprises pusher plate cam follower; (b) an L-shaped member 882 that is operatively connected to the first member 880; (c) a linear rail 884 that is operatively connected to the base plate 800; (d) a pair of mounts 886A, 886B that connect the L-shaped member 882 to the linear rail 884; and (e) a roller assembly 888 that also connects the first member 880 to the base plate 800 and allows the first member 880 to move relative to the base plate 800. The linear rail 884 and pair of mounts 886A, 886B operate to constrain the movement of the gripper assembly 802 to linear movement towards and away from locations at which a data cartridge is located or can be located. Other types of base plate assemblies that are capable of being used to move a gripper assembly towards and away from locations at which a data cartridge is or can be located are feasible.

[0145] The first member 800 comprises a pusher cam follower surface 894 that interacts with a pusher plate cam driver associated with the crank assembly 806 to move the pusher plate assembly 804 to a desired location along the linear rail 884. Generally, the cam follower surface 894 is comprised of two, parallel surfaces 896A, 896B. The application of a force by the pusher plate cam driver to the

surface 896A drives the pusher plate assembly 804 away from the elevator 582. Conversely, the application of a force by the pusher plate cam driver to the surface 896B drives the pusher plate assembly 804 towards the elevator 582. Forming a portion of the surface 896A is a compliance member 898 that flexes to reduce the force being applied by the pusher plate cam driver to a data cartridge that has been contacted by the grasper assembly 802. In the illustrated embodiment, the compliance member 898 is comprised of a flat spring 900 that is located in a recess 902. One end of the spring 900 is fixed to the first member 880 and the other end of the spring 900 floats within the recess 902 to allow the spring 900 to flex. Forming a portion of the surface 896B is a dwell 904 that prevents the pusher plate cam driver from applying a force to the pusher plate assembly 804 over the extent of the dwell 898.

[0146] The crank assembly 806 is comprised of: (a) a motor assembly 910 for providing a rotational motive force; (b) a crank 912 for rotating about an axis 913 in response to the rotational motive force provided by the motor assembly; and (c) a camming structure 914 that provides a grasper cam driver surface for interacting with a grasper

cam follower and a pusher plate cam driver surface for interacting with a pusher plate cam follower, and moves through the operation of the motor assembly 910 and the crank 912.

[0147] The motor assembly 910 is comprised of: (a) a stepper motor 920 that is attached to the base plate 800; and (b) a pinion 922 that is attached to the spindle of the stepper motor 920. The stepper motor 920 is capable of rotating the pinion 922 in a clock-wise direction and a counter-clockwise direction.

[0148] The crank 912 is comprised of : (a) a crank spindle 928 that is attached to the base plate 800; (b) a crank top 930; (c) an inner gear 932 that is attached to the crank top 930 and that engages the pinion 922 that is associated with the stepper motor 920; and (d) a bearing assembly 934 that connects the crank top 930 and the inner gear 932 to the spindle 928.

[0149] The camming structure 914 is operatively attached to the crank top 930 and is comprised of a cylindrical surface 940 and a spherical surface 942. All or a substantial portion of the cylindrical surface 940 is the pusher plate cam driver surface that interacts with the pusher plate cam follower surface 894 to move the pusher plate assembly 804.



The cylindrical surface 940 has a surface vector that is substantially perpendicular to the axis 913. Pusher plate cam driver surfaces that are other than cylindrical surfaces are feasible provided the surface is capable of interacting with a pusher plate cam follower surface to move the pusher plate to the desired location. At least a portion of the spherical surface 942 is the grasper cam driver surface that interacts with the grasper cam follower 830 to force the second surface 826 associated with the upper jaw 836 to move towards the "open" position.

[0150] Associated with the crank assembly 806 is a crank position sensing system 948 that is comprised of: (a) a 50/50 flag 950 that is attached to the underside of the crank top 930 and used to determine whether the crank 912 is within a first 180 degree range of operation or a second 180 degree range of operation that does not substantially overlap with the first 180 degree range of operation; (b) a 50/50 flag sensor 952 for detecting the 50/50 flag; (c) a plurality of pins 954 that are attached to the underside of the crank top 930 and used to determine where the crank 912 is operating to a greater degree of accuracy than is possible with the 50/50 flag 950; and (d) an encoder sensor 956 for detecting pins associated with the plurality of

pins 954.

- [0151] Also associated with the picker 580 is a calibration sensor 962 that is used to orient and/or calibrate the positioning systems within the library 100 by detecting the orientation structures 368A, 368B associated with the entry/exit port magazine 310, the top surfaces of the slit defining structures 418 of the magazines in the magazine structure 106, and drive orientation structures associated 964 (see Fig. 9B) with the frame 442 of the drive bay 108.
- [0152] Further associated with the picker 580 is a bar code sensor 966 that is used to detect a bar code that is associated with an entry/exit port magazine 310 and bar codes associated with data cartridges located within the library 100.
- [0153] With reference to Figs. 15A1–15D2, the operation of the picker 580 in grasping an LTO data cartridge 980 is described. Figures 15A1 and 15A2 illustrate the situation in which: (a) the picker 580 has been positioned adjacent to the data cartridge 980 that is to be grasped; and (b) the pusher plate assembly 804 is fully retracted, i.e., the crank assembly 806 has been used to position the pusher plate assembly 804 as close to the elevator 582 as is possible. In this state, a portion of the spherical surface 942 is engaging the horizontal surface 860 of the grasper cam

follower 830. As a consequence, the moving member 824 is positioned such that the second surface 826 and the first surface 822 are in the "open" position, i.e., incapable of grasping a data cartridge. Further, the flag assembly 870 of the tape-in-jaw sensory system 868 is in a state that indicates that there is no tape located between the first surface 822 and the second surface 826.

[0154] Figures 15B1 and 15B2 illustrate the state of the picker 580 and the data cartridge 980 after the crank 912 has rotated the camming structure 914 in a counter-clockwise direction 984 though about 180 degrees relative to position of the camming structure 914 shown in Figs. 15A1 and 15A2. The rotation of the camming structure 914 has caused the pusher plate cam driver portion of the cylindrical surface 940 to apply a force to the pusher cam follower surface 896A that has moved the pusher plate assembly 804 from the position shown in Fig. 15A1 to the position shown in Fig. 15A2. At this point, the spherical surface 942 is still engaging the horizontal surface 860 of the grasper cam follower 830. Consequently, the first surface 822 and the second surface 826 of the grasper assembly 802 are still in the "open " position. Since the data cartridge 980 is now in between the first surface 822 and

the second surface 826, the flag assembly 870 is now in a state that indicates this condition. However, the flag assembly 870 is not yet positioned so that the plunger can be detected by the sensor 872.

[0155] Figures 15C1 and 15C2 illustrate the state of the picker 580 and the data cartridge 980 after the crank 912 has slightly further rotated the camming structure 914 in the counter-clockwise direction 984 relative to the rotational position of the camming structure 914 shown in Figs. 15B1 and 15B2. Due to the operation of the compliance member 898, the further rotation has resulted in little, if any, further linear displacement of the pusher plate assembly 804. The spherical surface 942 is, due to the further rotation, no longer in contact with the grasper cam follower 830. As a consequence, the bias system 828 has caused the second surface 826 to move towards the first surface 822 and the cartridge 980 to be grasped. The flag assembly 870 is still in a state that indicates that a cartridge is located between the first surface 822 and the second surface 826. Further, the flag assembly 870 is still not positioned so that the sensor 872 can detect the plunger associated with the assembly.

[0156] Figures 15D1 and 15D2 illustrate the state of the picker

580 and the data cartridge 980 after the crank 912 has further rotated the camming structure 914 in the counter-clockwise direction 984 through about 180 degrees relative to position of the camming structure 914 shown in Figs. 15B1 and 15B2, i.e. almost back to the fully retracted position. The further rotation of the camming structure 914 has caused the pusher plate cam driver portion of the cylindrical surface 940 to apply a force to the pusher cam follower surface 896B that has moved the pusher plate assembly 804 from the position shown in Fig. 15B1 to the position shown in Fig. 15D2. The spherical surface 942 is still not in contact with the grasper cam follower 830. As a consequence, the first surface 822 and the second surface 826 are still grasping the cartridge 980. The flag assembly 870 is still in a state that indicates that the cartridge is located between the first surface 822 and the second surface 826. However, the plunger associated with the flag assembly 870 is now positioned so that the sensor 872 can detect the plunger. The facts that the sensor 872 has detected that the data cartridge 980 is located between the first surface 822 and the second surface 826 and that the pusher plate assembly 804 is at or near to the fully retracted position dictate that any subsequent rotation of

the crank 912 must be in the clockwise direction. Further rotation of the crank 912 in the counter-clockwise direction would result in the second surface 826 being displaced away from the first surface, which could result in the cartridge being dropped. Insertion of the grasped data cartridge into a location that is capable of holding the cartridge is accomplished by reversing the noted operations, which involves clockwise rotation of the crank 912.

[0157] It should be appreciated that the picker 580 operates such that: (a) for a first range of the rotation of the crank 912, the grasper assembly 802 is in the open position and incapable of grasping a cartridge, and (b) for a second range of rotation of the crank 912 that does not substantially overlap with the first range, the grasper assembly 802 is in the closed position that allows a cartridge to be grasped. With reference to Figs. 16A–16D, the ranges over which the grasper assembly 802 is in the open position, closed position, and transitioning between the open and closed positions are illustrated. Figure 16A, which corresponds to Figs. 15A1 and 15A2, illustrates the spherical surface 942 engaging the horizontal surface 860 of the grasper cam follower 830 at a point immediately adjacent to the transitional surface 862 of the grasper cam fol-

lower. Consequently, Fig. 16A illustrates an approximate first end point 990 of the first range of rotation of the crank 912 during which the grasper assembly 802 is in the open position. Figure 16B, which corresponds to Figs. 15B1 and 15B2, shows the spherical surface 942 engaging the horizontal surface 860 of the grasper cam follower 830 at point immediately adjacent to the transitional surface 862 after the crank 912 has rotated the camming structure 914 through approximately 180 degrees relative to the position of the camming structure 914 shown in Fig. 16A. At this point, the grasper assembly 802 is still in the open position. Consequently, Fig. 16B illustrates an approximate second end point 992 of the first range. As illustrated, the range between the first and second end points 990, 992, relative to a center line 994, is somewhat less than 180 degrees.

[0158] With reference to Fig. 16C, which corresponds to Figs. 15C1 and 15C2, the spherical surface 942 is not engaging the grasper cam follower 830 and is positioned at a point immediately adjacent to the transitional surface 862. At this point, the grasper assembly 802 is in the closed position. Consequently, Fig. 16C illustrates an approximate first end point 996 of the second range of rotation of the

crank 912 during which the grasper assembly 802 is in the closed position. Figure 16D, which corresponds to Figs. 15D1 and 15D2, shows the spherical surface 942 immediately adjacent to the transitional surface 862 of the grasper cam follower 830 after the crank 912 has rotated the camming structure 914 through approximately 180 degrees relative to the position of the camming structure 914 shown in Fig. 16C. Consequently, Fig. 16D illustrates an approximate second end point 998 of the second range. As illustrated, the range between the first and second end points 996, 998, relative to a center line 994, is somewhat less than 180 degrees.

[0159] Between the second end point 992 of the first range and the first end point 996 of the second range, the spherical surface 942 is engaging the transitional surface 862 of the grasper cam follower 830 and the grasper assembly 802 is between the open and closed positions. Similarly, between the second end point 998 of the second range and the first end point 990 of the first range, the spherical surface 942 is engaging the transitional surface 862 of the grasper cam follower 830 and the grasper assembly 802 is between the open and closed positions. When the grasper assembly 802 is between the open and closed po-



sitions, the ability of the grasper assembly 802 to grasp a cartridge is ambiguous. Consequently, the end points of the first and second ranges may lie in the ranges associated with the transition of the grasper assembly 802 between the open and closed positions. As such the first and second ranges may lie closer to 180 degrees or may exceed 180 degrees. In any event, the ranges are each approximately 180 degrees and do not substantially overlap.

[0160] It should be appreciated that picker can be designed such the grasper is in an open position for a first range of rotation of a crank and in a closed position for a second range of rotation of the crank that does not substantially overlap with the first range of rotation where the ranges are different than those illustrated in Figs. 16A–16D.

[0161] With reference to Figs. 12B, 13A and 13B, the library 100 further comprises a removable robotics module 740 that allows a user to readily remove substantially all of the electrical and mechanical components of the transport system 112 that could break or malfunction from the library 100 and replace all of those components by inserting another module into the library 100. As a consequence, any downtime for the library 100 that is associated with a broken or malfunctioning component of the

transport system 112 can be reduced.

[0162] The removable robotic module 740 comprises the robotic module tray 670 and, attached to the tray 670, the picker 580, most of the elevator 582, and a controller board 742 that provides control logic for the picker 580 and the elevator 582. The module 740 does not include the pulley 692, the bracket 694, the second shaft pulley 696, the bracket 698, the third timing belt 700, the portion of the connecting bracket 690 that remains connected to the timing belt 700 after the quick release device is actuated, the second shaft piece 704, or the spline sleeve 708.

[0163] The tray 670 of the module 740 is fixed in place in the library 100 by brackets 744A–744B that are attached to the side portion 184A of the bottom tray 186, brackets 746A–746B that are attached to the side portion 184B of the bottom tray 186, a bracket 748 that is attached to the mid-portion 190 of the bottom tray 186, and a threaded hole 750 that receives a captured screw 752 associated with the tray 670. The brackets 744A, 744B, 746A and 746B operate to engage the edge of the tray 670 and thereby vertically constrain the tray 670. The bracket 748 engages the edge of the tray 670 to both vertically and horizontally constrain the tray 670. The threaded hole

750, when engaged by the screw 752, also serves to vertically and horizontally constrain the tray 670.

[0164] Assuming the removable robotic module 740 is fixed in place within the library 100, removal of the module 740 involves: removing the front panel 176 to expose the module 740, unscrewing the screw 752 from the threaded hole 750, manipulating the spline sleeve 708 to disconnect the first shaft piece 702 and the second shaft piece 704, and manipulating the connecting bracket 701 to disconnect the top plate 622 from the third timing belt 700. In addition, an electrical connector that connects the controller board 742 and the control module 536 is disconnected. After these operations are completed, the module 740 can be slid out of the library 100 and, if desired, a replacement module inserted and connected to the library. After any replacement module has been connected to the library 100, the front panel 176 is replaced.

[0165] The foregoing is intended to describe the best mode known of practicing each of the inventions and to enable others skilled in the art to practice the inventions.